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## INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

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<b>(21) International Application Number:</b> PCT/US97/13501 <b>(22) International Filing Date:</b> 31 July 1997 (31.07.97)  <b>(30) Priority Data:</b> 08/695,954      12 August 1996 (12.08.96)      US  <b>(71) Applicant:</b> AUTOMOTIVE SYSTEMS LABORATORY, INC. [US/US]; Suite B-12, 27200 Haggerty Road, Farmington Hills, MI 48331 (US).  <b>(72) Inventors:</b> BURNS, Sean, P.; 1929 Plymouth Road, No. 4008, Ann Arbor, MI 48105 (US). MOQUIN, Larry, A.; 22472 Mansion Court, No. 105, Novi, MI 48375 (US). KHANDHADIA, Paresh, S.; 6697 Redford Circle, Troy, MI 48098 (US).  <b>(74) Agent:</b> LYON, Lyman, R.; Lyon, P.C., Suite 207, 3883 Telegraph Road, Bloomfield Hills, MI 48302-1476 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>Without international search report and to be republished upon receipt of that report.</i>
<b>(54) Title:</b> SELECTIVE NON-CATALYTIC REDUCTION (SNCR) OF TOXIC GASEOUS EFFLUENTS IN AIRBAG INFLATORS  <b>(57) Abstract</b>  NH <sub>2</sub> radical-generating compounds, independent of the gas generant composition, reduce the toxicity of effluent gases produced by combustion of nonazide gas generating compositions used to inflate vehicle occupant restraint systems. By selective reactive of the NH <sub>2</sub> radical with NO in the combustion gas, N <sub>2</sub> is formed thereby decreasing the concentration of toxic nitrogen oxides therein. Placement of the reducing compounds proximate to the gas generant bed ensures intimate contact with the combustion gases, and yet still provides a noninvasive method of toxic gas reduction.		

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**SELECTIVE NON-CATALYTIC REDUCTION (SNCR) OF TOXIC  
GASEOUS EFFLUENTS IN AIRBAG INFLATORS**

**BACKGROUND OF THE INVENTION**

The present invention relates generally to inflatable  
5 occupant safety restraints in motor vehicles, and more  
particularly to reducing the toxicity of effluent gases  
produced by nonazide gas generating compositions.

Inflatable occupant restraint devices for motor  
vehicles have been under development worldwide for many years,  
10 including the development of gas generating compositions for  
inflating such occupant restraints. Because the inflating  
gases produced by the gas generants must meet strict toxicity  
requirements, many gas generants now in use are based on alkali  
or alkaline earth metal azides, particularly sodium azide.  
15 When reacted with an oxidizing agent, sodium azide forms a  
relatively nontoxic gas consisting primarily of nitrogen.

However, azide-based gas generants are inherently  
volatile to handle and entail relatively high risk in  
manufacture and disposal. More specifically, whereas the  
20 inflating gases produced by azide-based gas generants are  
relatively nontoxic, the metal azides themselves are conversely  
highly toxic, thereby resulting in extra expense and risk in  
gas generant manufacture, storage, and disposal. In addition  
to direct contamination of the environment, metal azides also  
25 readily react with acids and heavy metals to form extremely  
sensitive compounds that may spontaneously ignite or detonate.

In contradistinction, nonazide gas generants, such as  
those disclosed in U.S. Patent No. 5,139,588 to Poole,  
typically comprise a nonazide fuel selected from the group of  
30 tetrazole compounds and metal salts thereof, and provide  
significant advantages over azide-based gas generants with  
respect to toxicity related hazards during manufacture and  
disposal. Moreover, most nonazide gas generant compositions  
typically supply a higher yield of gas (moles of gas per gram

of gas generant) than conventional azide-based occupant restraint gas generants.

However, many nonazide gas generants heretofore known and used produce high levels of toxic substances upon combustion. The most difficult toxic gases to control are the various oxides of nitrogen ( $\text{NO}_x$ ) and carbon monoxide (CO). Because the gas generant of the passenger-side airbags is generally four times greater than that of the driver-side, the need for  $\text{NO}_x$  and CO reduction is most keenly felt when designing passenger-side airbags, although the concern exists for other airbag systems within the vehicle as well.

Reduction of the level of toxic  $\text{NO}_x$  and CO upon combustion of nonazide gas generants has proven to be a difficult problem. For instance, manipulation of the oxidizer/fuel ratio only reduces either the  $\text{NO}_x$  or CO. More specifically, increasing the ratio of oxidizer to fuel minimizes the CO content upon combustion because the extra oxygen oxidizes the CO to carbon dioxide. Unfortunately, however, this approach results in increased amounts of  $\text{NO}_x$ . Alternatively, if the oxidizer/fuel ratio is lowered to eliminate excess oxygen and reduce the amount of  $\text{NO}_x$  produced, increased amounts of CO are produced.

One way to improve the toxicity of the combustion gases is to reduce the combustion temperature which would reduce the initial concentrations of both CO and  $\text{NO}_x$ . Although simple in theory, it is difficult in practice to reduce the combustion temperature and to also retain a sufficiently high gas generant burn rate for practical application in an inflatable vehicle occupant restraint system. The burn rate of the gas generant is important to insure that the inflator will operate readily and properly. As a general rule, the burn rate of the gas generant decreases as the combustion temperature decreases. By using less energetic fuels, specifically fuels which produce less heat upon combustion, the combustion temperature may be reduced but the gas generant burn rate is also reduced.

Therefore, a need still exists for reducing the toxicity of effluent gases produced by nonazide gas generants without compromising the gas generant properties.

#### SUMMARY OF THE INVENTION

5           The aforesaid problems are solved, in accordance with the present invention, by a nonazide gas generating composition which in and of itself is nontoxic, and which upon combustion, also produces inflating gases that have reduced levels of NO<sub>x</sub> and CO due to the use of a compound that generates NH<sub>2</sub> radicals  
10       in the gas phase. Selective non-catalytic reduction (SNCR) employs an NH<sub>2</sub> radical that selectively reacts with nitrogen oxide (NO) in the gas phase to form non-toxic nitrogen gas (N<sub>2</sub>). In an SNCR system, basic requirements for the reduction of NO by an SNCR chemical include a well-mixed minimal 1:1  
15       ratio of NH<sub>2</sub> radical to NO, whereby the NH<sub>2</sub> radical is generated by the SNCR chemical and the NO is generated from the gas generant combustion. Furthermore, the NH<sub>2</sub> radical must react for a sufficient residence time at a temperature within the range of 850-1150°C. The reduced content of toxic gases, such  
20       as NO<sub>x</sub> and CO, allows the use of nonazide gas generants in vehicle occupant restraint systems while protecting the occupants of the vehicle from exposure to toxic gases which heretofore have been produced by nonazide gas generants.

          More specifically, the present invention comprises a  
25       nonazide gas generant composition, and a separate NO<sub>x</sub> reducing agent (SNCR) chemical that liberates NH<sub>2</sub> radical upon thermal decomposition and/or reaction with O<sub>2</sub>. The NO<sub>x</sub> gases generated from the combustion of the gas generant, such as NO and NO<sub>2</sub>, selectively react with the NH<sub>2</sub> radicals, or NH<sub>3</sub> and O<sub>2</sub>, thereby  
30       producing a harmless gas of N<sub>2</sub>. A corresponding reduction in CO is an incidental benefit with the use of some of the reducing agents, such as (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>. In addition, the chemistry of the SNCR chemical is noninvasive and will not interfere with the expected performance or stability of a gas generant  
35       combustion.

DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENT(S)

In accordance with the present invention, a vehicle occupant restraint device utilizing an SNCR system comprises a gas generant and a de-NO<sub>x</sub> agent. The de-NO<sub>x</sub> agent is disposed  
5 around the periphery of the gas generant within the gas generant bed and is selected from a group including amides and imides, ammonium compounds, amine compounds, or any compound which produces an NH<sub>2</sub> radical in the gas phase. Examples of ammonium compounds include ammonium hydroxide (NH<sub>4</sub>OH), ammonium  
10 carbonate ((NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub>), ammonium sulfate ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>), ammonium chloride (NH<sub>4</sub>Cl), ammonium carbamate (H<sub>2</sub>NCO<sub>2</sub>NH<sub>4</sub>), and ammonium fluoride (NH<sub>4</sub>F). Examples of amide and imide compounds, respectively, compounds are urea (H<sub>2</sub>NCONH<sub>2</sub>) and cyanuric acid ((HNCO)<sub>3</sub>). Given the aforementioned benefits, the gas  
15 generant is preferably nonazide, although other gas generants such as an azide-based composition may be utilized in conjunction with SNCR. The SNCR chemical is preferably ammonium sulfate ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>) based on the optimum and unexpected results given in Example 3 below. Not only does (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>  
20 inhibit production of toxic NO<sub>2</sub>, it actually reduces NO<sub>2</sub> over time. In general, ammonium compounds will generate the highest yield of NH<sub>2</sub> radicals.

SNCR is well known and commonly used in industrial boilers to decrease the levels of toxic nitrogen oxides. Until  
25 now, SNCR technology has not been successfully implemented in automotive airbag systems. NO is reduced to N<sub>2</sub> by the following gas phase reaction with an NH<sub>2</sub> radical:

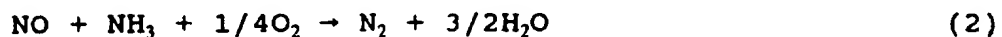


Because NO<sub>2</sub> is generated by NO, a reduction in NO necessarily  
30 causes an overall NO<sub>x</sub> reduction within the inflator gas. The critical parameters for the successful implementation of SNCR in any system are the reaction temperature, NH<sub>2</sub> radical/NO ratio, mixing, residence time, and initial NO level. In

addition, the presence of oxygen (O<sub>2</sub>) is critical when the SNCR chemical is ammonia or an ammonium compounds.

To obtain NH<sub>2</sub> radical in the gas phase at the correct level, the SNCR chemical must thermally decompose to generate the NH<sub>2</sub> radical or NH<sub>3</sub> (which must subsequently react with O<sub>2</sub> to form the NH<sub>2</sub> radical). The decomposition products determine how much of the NH<sub>2</sub> radical is generated in the gas phase versus what is liberated directly from the SNCR chemical. The minimum NH<sub>2</sub> radical/NO ratio in the gas phase reaction should be 1 mole of NH<sub>2</sub> radical for each mole of NO. In general, a small excess of the NH<sub>2</sub> radical will simply result in the formation of small amounts of NH<sub>3</sub> and provide minimal additional NO reduction. SNCR technology is most effective at high initial levels of NO. When ammonium compounds are used, oxygen is necessary for the formation of NH<sub>2</sub> radicals, and should be present at levels of 0.1 to 11 volume percent.

The decomposition temperature, determinative of when NH<sub>2</sub> radicals are generated in the gas phase, is critical because the NH<sub>2</sub> radical must be "injected" into the gas phase at the correct temperature thereby enabling the selective reduction reaction of NO<sub>x</sub>. For example, (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> decomposes at about 235°C while (NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub> begins to decompose at room temperature. During an inflator deployment, an SNCR chemical that decomposes at a lower temperature will be "injected" into the system sooner and, as illustrated in Example 4, provide a decreased reduction of nitrogen oxides. The importance of temperature is demonstrated by the following reactions:



The desired reaction, (2), will only occur at a significant rate at temperatures above 850-950°C. However, at temperatures above 1050-1150°C, reaction (3) becomes dominant and undesirable NO is formed. In addition to temperature, the

importance of good mixing and a sufficient residence time are obvious for the completion of any gas phase reaction. Th gas temperatures, degree of mixing, and residence time for a given inflator are determined primarily by the gas generant properties and the inflator configuration and operating conditions.

The temperature of the gases in an inflator will generally vary from the hottest at the generant burning surface to the coolest at the inflator exit ports. Although temperature is extremely difficult to measure, variables such as the thermodynamic properties of the generant, the burning rate of the generant, the cooling devices within the inflator, and the operating pressure of the inflator each contribute to the overall operating temperature of the SNCR system. The residence time of the gases in an inflator is dependent on the presence of choked flow and the operating pressure. One skilled in the art will readily realize that cognizance and tailoring of these variables when choosing a gas generant will enable the use of a wide variety of gas generant compositions in conjunction with the SNCR system.

In accordance with the present invention, the SNCR chemical is a noninvasive composition whereby the normal combustion reaction of the gas generant is not interrupted or significantly altered. The present invention is illustrated by the following examples.

#### EXAMPLE 1

Two nonazide passenger inflators (NAPIs) with the same gas generant and hardware were built. Ammonium carbonate ( $(\text{NH}_4)_2\text{CO}_3$ ) was added directly to the generant bed of one of the inflators as a powder at 1.4 wt% of the generant mass. The inflators were deployed in a 100 ft<sup>3</sup> tank and the gaseous effluents were measured over a 30 minute time period. Carbon monoxide (CO) and ammonia ( $\text{NH}_3$ ) were measured by FTIR while nitrogen (II) oxide (NO), nitrogen (IV) oxide ( $\text{NO}_2$ ), and total nitrogen oxides ( $\text{NO}_x$ ) were measured by Chemiluminescence. The time weighted averages are reported below in ppm.



Inflator	CO	NO	NO <sub>2</sub>	NO <sub>x</sub>	NH <sub>3</sub>
Control	665	85.7	29.6	117.6	14
1.4% (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub>	705	52.8	0.9	53.6	96
Percent of Control	106%	62%	3%	46%	686%

This example illustrates that the addition of this SNCR ammonium salt significantly reduces the levels of toxic nitrogen oxides while leaving the CO essentially unchanged.

#### EXAMPLE 2

5 Two NAPIs with the same gas generant and hardware were built and tested as described in Example 1. However, the generant load and the cooling assembly differed from that used in Example 1. ((NH<sub>4</sub>)<sub>2</sub>CO<sub>3</sub>) was added directly to the generant bed of one of the inflators as a powder at 2.6 wt% of the  
10 generant mass. The time weighted averages are reported below in ppm.

Inflator	CO	NO	NO <sub>2</sub>	NO <sub>x</sub>	NH <sub>3</sub>
Control	822	106.1	50.5	162	16
2.6% (NH <sub>4</sub> ) <sub>2</sub> CO <sub>3</sub>	798	82.0	30.7	116	147
Percent of Control	97%	77%	61%	72%	919%

15 This example demonstrates the importance of choosing the correct inflator configuration for successful implementation of SNCR technology in an airbag inflator. In addition, this example shows that an excess of an SNCR chemical does not  
20 result in further NO<sub>x</sub> reduction, but only in higher levels of NH<sub>3</sub> production.

#### EXAMPLE 3

25 Two NAPIs with the same gas generant and hardware were built and tested as described in Example 1. However, the generant load and the cooling assembly differed from that of Examples 1 and 2. (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> was added directly to the generant bed of one of the inflators as a powder at 1.2 wt % of the generant mass. The time weighted averages are reported below in ppm.

Inflator	CO	NO	NO <sub>2</sub>	NO <sub>x</sub>	NH <sub>3</sub>
Control	437	59.6	12.5	73.3	8
1.2% (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	406	62.2	5.2	67.7	57
Percent of Control	93%	104%	42%	92%	712

5 Two quite unexpected, yet beneficial results were observed from these tests. First, the addition of ((NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub>) resulted in a reduction of both NO<sub>x</sub> and CO. Secondly, a comparison of the NO<sub>2</sub> evolution in the control and in the SNCR samples indicates a decline over time of the NO<sub>2</sub> species in the  
10 SNCR sample and an increase in the NO<sub>2</sub> species in the control sample. For the control inflator, the NO<sub>2</sub> was 9.4 ppm at 3 minutes and 16.4 ppm at 30 minutes. This is what is normally seen since the NO initially produced by the inflator slowly converts to NO<sub>2</sub> in the presence of O<sub>2</sub>. For the inflator with  
15 the SNCR chemical, the NO<sub>2</sub> was 7.8 ppm at 3 minutes and steadily decreased to 5.0 ppm at 30 minutes. This example illustrates the effectiveness of this embodiment in retarding the generation of toxic NO<sub>2</sub>, despite the presence of increased amounts of relatively nontoxic NO and O<sub>2</sub>.

#### 20 EXAMPLE 4

Four NAPIs with the same gas generant and hardware were built and tested as described in Example 1. However, the generant load and the cooling assembly differed from that used in Examples 1, 2, or 3. (NH<sub>4</sub>)<sub>2</sub>SO<sub>4</sub> (decomposes at 235°C) and  
25 H<sub>2</sub>NCO<sub>2</sub>NH<sub>4</sub> (sublimes at 60°C) were each added directly to the generant bed of one of the inflators as a powder at 2.7 wt % of the generant mass. The time weighted averages are reported below in ppm.

Inflator	CO	NO	NO <sub>2</sub>	NO <sub>x</sub>	NH <sub>3</sub>
Control	552	82.2	30.2	115.2	10
2.7% (NH <sub>4</sub> ) <sub>2</sub> SO <sub>4</sub>	453	81.5	6.2	66.2	105
2.7% H <sub>2</sub> NCO <sub>2</sub> NH <sub>4</sub>	715	79	31	112.9	196

Again, the addition of  $(\text{NH}_4)_2\text{SO}_4$  resulted in a reduction of  $\text{NO}_x$  and CO. Also, the  $\text{NO}_2$  level went from 9.4 ppm at 3 minutes to 5.6 ppm at 30 minutes, verifying the data shown in Example 3. The decomposition and sublimation points of the different compounds are provided to demonstrate that the decomposition temperature must be considered as a critical factor to the success of the SNCR chemical.

While the preferred embodiment of the invention has been disclosed, it should be appreciated that the invention is susceptible of modification without departing from the scope of the following claims.

WE CLAIM:

1. A vehicle occupant restraint system comprising:  
an inflatable air bag;  
a gas generator;  
a gas generant compound located within said gas  
generator; and  
a selective non-catalytic reducing compound  
proximate to and interspersed about said gas  
generant compound, placed wherein said  
selective non-catalytic reducing compound is  
selected from the group comprising ammonium  
salts, ammonium hydroxide ( $\text{NH}_4\text{OH}$ ), amine  
compounds, and amide and imide compounds.
2. A vehicle occupant restraint system of Claim 1  
wherein:  
said gas generant comprises a nonazide composition;  
said ammonium salt is selected from a group  
consisting of ammonium hydroxide ( $\text{NH}_4\text{OH}$ ),  
ammonium carbonate ( $(\text{NH}_4)_2\text{CO}_3$ ), ammonium sulfate  
( $(\text{NH}_4)_2\text{SO}_4$ ), ammonium chloride ( $\text{NH}_4\text{Cl}$ ), ammonium  
carbamate ( $\text{H}_2\text{NCO}_2\text{NH}_4$ ), and ammonium fluoride  
( $\text{NH}_4\text{F}$ ); and  
said amide compound is selected from a group  
consisting of urea ( $\text{H}_2\text{NCONH}_2$ ); and  
said imide compound is selected from a group  
consisting of cyanuric acid ( $(\text{HNCO})_3$ ).
3. A method of reducing the toxicity of effluent gases  
of a gas generator, used to inflate an airbag of a vehicle  
occupant restraint system, comprising the step of:

interspersing a selective non-catalytic reducing compound about a gas generant composition within the gas generator; and

5 reacting with gaseous products of the selective non-catalytic reducing compound with the gaseous combustion products of the gas generant composition.

4. A vehicle occupant restraint system of Claim 1 wherein:

said gas generant compound consists of a nonazide composition; and

5 said selective non-catalytic reducing compound consists of an ammonium salt selected from a group consisting of ammonium carbonate  $((\text{NH}_4)_2\text{CO}_3)$ , ammonium sulfate  $((\text{NH}_4)_2\text{SO}_4)$ , ammonium chloride  $(\text{NH}_4\text{Cl})$ , ammonium carbamate  $(\text{H}_2\text{NCO}_2\text{NH}_4)$ , and ammonium fluoride  $(\text{NH}_4\text{F})$ .

10 5. A vehicle occupant restraint system of Claim 1 wherein:

said gas generant compound consists of a nonazide composition; and

said selective non-catalytic reducing compound consists of urea  $(\text{H}_2\text{NCONH}_2)$ .

6. A vehicle occupant restraint system of Claim 1 wherein:

said gas generant compound consists of a nonazide composition; and

said selective non-catalytic reducing compound consists of cyanuric acid  $((\text{HNCO})_3)$ .

7. A vehicle occupant restraint system of Claim 1 wherein:

said gas generant compound consists of a nonazide composition; and

said selective non-catalytic reducing compound consists of ammonium hydroxide ( $\text{NH}_4\text{OH}$ ).

8. A vehicle occupant restraint system of Claim 1 wherein:

said gas generant compound consists of a nonazide composition; and

said selective non-catalytic reducing compound consists of an amine compound.

9. The method of claim 3 wherein:

said selective non-catalytic reducing compound consists of an ammonium salt selected from a group consisting of ammonium carbonate ( $(\text{NH}_4)_2\text{CO}_3$ ), ammonium sulfate ( $(\text{NH}_4)_2\text{SO}_4$ ), ammonium chloride ( $\text{NH}_4\text{Cl}$ ), ammonium carbamate ( $\text{H}_2\text{NCO}_2\text{NH}_4$ ), and ammonium fluoride ( $\text{NH}_4\text{F}$ ).

10. The method of claim 3 wherein:

said selective non-catalytic reducing compound consists of urea ( $\text{H}_2\text{NCONH}_2$ ).

11. The method of claim 3 wherein:

said selective non-catalytic reducing compound consists of cyanuric acid ( $(\text{HNCO})_3$ ).

12. The method of claim 3 wherein:

said selective non-catalytic reducing compound consists of ammonium hydroxide ( $\text{NH}_4\text{OH}$ ).

13. A vehicle occupant restraint system of Claim 1 wherein:

said selective non-catalytic reducing compound consists of an amine compound.

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<b>(21) International Application Number:</b> PCT/US97/13501 <b>(22) International Filing Date:</b> 31 July 1997 (31.07.97)  <b>(30) Priority Data:</b> 08/695,954 12 August 1996 (12.08.96) US  <b>(71) Applicant:</b> AUTOMOTIVE SYSTEMS LABORATORY, INC. [US/US]; Suite B-12, 27200 Haggerty Road, Farmington Hills, MI 48331 (US).  <b>(72) Inventors:</b> BURNS, Sean, P.; 1929 Plymouth Road, No. 4008, Ann Arbor, MI 48105 (US). MOQUIN, Larry, A.; 22472 Mansion Court, No. 105, Novi, MI 48375 (US). KHANDHADIA, Paresh, S.; 6697 Redford Circle, Troy, MI 48098 (US).  <b>(74) Agent:</b> LYON, Lyman, R.; Lyon, P.C., Suite 207, 3883 Telegraph Road, Bloomfield Hills, MI 48302-1476 (US).		<b>(81) Designated States:</b> AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GE, HU, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, TJ, TM, TR, TT, UA, UG, UZ, VN, ARIPO patent (GH, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).  <b>Published</b> <i>With international search report.</i> <i>Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i>  <b>(88) Date of publication of the international search report:</b> 9 July 1998 (09.07.98)
<b>(54) Title:</b> SELECTIVE NON-CATALYTIC REDUCTION (SNCR) OF TOXIC GASEOUS EFFLUENTS IN AIRBAG INFLATORS  <b>(57) Abstract</b>  NH <sub>2</sub> radical-generating compounds, independent of the gas generant composition, reduce the toxicity of effluent gases produced by combustion of nonazide gas generating compositions used to inflate vehicle occupant restraint systems. By selective reactive of the NH <sub>2</sub> radical with NO in the combustion gas, N <sub>2</sub> is formed thereby decreasing the concentration of toxic nitrogen oxides therein. Placement of the reducing compounds proximate to the gas generant bed ensures intimate contact with the combustion gases, and yet still provides a noninvasive method of toxic gas reduction.		

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## INTERNATIONAL SEARCH REPORT

 International application No.  
PCT/US97/13501

## A. CLASSIFICATION OF SUBJECT MATTER

IPC(6) : B60R 21/28; C06B 23/02

US CL : 280/741; 149/108.4

According to International Patent Classification (IPC) or to both national classification and IPC

## B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

U.S. : 280/741; 149/108.4

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

## C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
Y	US 3,715,131 A (HURLEY et al.) 06 February 1973, the Abstract and col. 3, lines 13-17.	1-2, 5
Y	US 3,785,674 A (POOLE et al.) 15 January 1974, col. 2, lines 28-31.	1-2, 5
Y	US 3,797,854 A (POOLE et al.) 19 March 1974, the Abstract, col. 7, lines 14-18.	1-2, 5
Y	US 5,538,567 A (HENRY III et al.) 23 July 1996, the Abstract, col. 4, lines 24-26.	1-2, 5
Y	US 5,460,668 A (LYON) 24 October 1995, the Abstract, col. 2, lines 5-12, col. 3, lines 28-29.	1-2, 5
A	US 3,721,102 A (GREEN) 20 March 1973.	1

☒ Further documents are listed in the continuation of Box C.
 ☐ See patent family annex.

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Date of the actual completion of the international search

26 APRIL 1998

Date of mailing of the international search report

14 MAY 1998

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## INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/13501

## C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 5,501,823 A (LUND et al.) 26 March 1996.	1

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/13501

## Box I Observations where certain claims were found unsearchable (Continuation of Item 1 of first sheet)

This international report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☐ Claims Nos.:  
because they relate to subject matter not required to be searched by this Authority, namely:-
  
2. ☒ Claims Nos.: 10-13  
because they relate to parts of the international application that do not comply with the prescribed requirements to such an extent that no meaningful international search can be carried out, specifically:  
  
since they depend on omitted claim 4. Although a paper was filed referring to a correction being made, such is not of record in the file.
  
3. ☐ Claims Nos.:  
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

## Box II Observations where unity of invention is lacking (Continuation of Item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

Please See Extra Sheet.

1. ☐ As all required additional search fees were timely paid by the applicant, this international search report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
3. ☐ As only some of the required additional search fees were timely paid by the applicant, this international search report covers only those claims for which fees were paid, specifically claims Nos.:
  
4. ☒ No required additional search fees were timely paid by the applicant. Consequently, this international search report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:  
1-2 and 5, e.g., Species A of Group I.

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.  
☐ No protest accompanied the payment of additional search fees.

# INTERNATIONAL SEARCH REPORT

International application No.  
PCT/US97/13501

## BOX II. OBSERVATIONS WHERE UNITY OF INVENTION WAS LACKING

This ISA found multiple inventions as follows:

This application contains the following inventions or groups of inventions which are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for all inventions to be searched, the appropriate additional search fees must be paid.

Group I, claim(s) 1-2, 5-9 and 14, drawn to a device.

Group II, claim(s) 3, drawn to a method.

This application contains claims directed to more than one species of the generic invention. These species are deemed to lack Unity of Invention because they are not so linked as to form a single inventive concept under PCT Rule 13.1. In order for more than one species to be searched, the appropriate additional search fees must be paid. The species are as follows:

- A) a device or method with an inorganic ammonium salt SNCR.
- B) a device or method with an organic compound SNCR.
- C) a device or method with an ammonium hydroxide SNCR.

The claims are deemed to correspond to the species listed above in the following manner:

- A) Claim 5.
- B) Claims 6, 7, 9 and 14.
- C) Claim 8.

The following claims are generic: 1-3

The inventions listed as Groups I and II do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, they lack the same or corresponding special technical features for the following reasons: The Group II method is not a method of using the device of Group I. There is no gas bag in the Group II method, e.g. Therefore, the Group II method neither makes nor uses the device of Group I, but is independent therefrom. Further, to the extent that some special technical feature might exist, the Groups are not limited thereto, but include features that are not novel, e.g.

The species listed above do not relate to a single inventive concept under PCT Rule 13.1 because, under PCT Rule 13.2, the species lack the same or corresponding special technical features for the following reasons: Obviously, organic compounds (which have oxidizable carbon content) and inorganic salts (lacking oxidizable carbon content, e.g.) are not the same special technical feature. Further, ammonium hydroxide is the only species that would necessarily be present as an aqueous solution. The generic claims are also not limited to novel, e.g., species.